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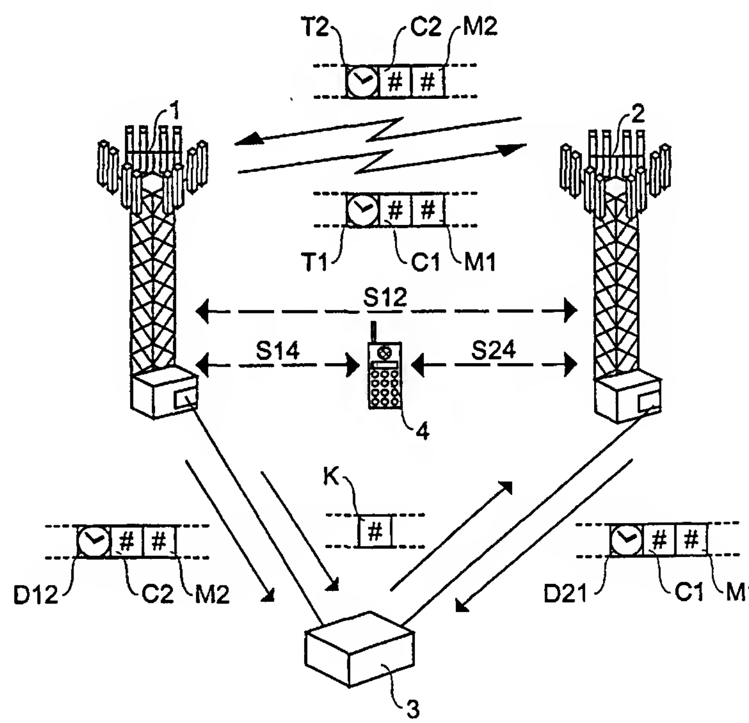
(54) Title: METHOD AND SYSTEM TO SYNCHRONISE BASE STATIONS IN DIGITAL TELECOMMUNICATION NETWORKS

(57) Abstract

Method to reciprocally synchronize at least one pair of base stations (1, 2) belonging to a digital telecommunication network, in which the radio signals transmitted and received by said stations (1, 2) are subdivided into frames having pre–set duration and each frame is subdivided into a pre–set number of time slots including at least one field destined to the transmission of frame synchronization data (T1, T2), characterized in that it includes the following operating steps: transmitting by said pair of stations (1, 2) a radio signal containing at least its own frame synchronization data (T1, T2); receiving by said pair of stations (1, 2) the frame synchronization data (T2, T1) transmitted by the other station (2, 1); calculating by said pair of stations (1, 2) the phase shift values (D12, D21) between its own frame synchronization data (T1, T2) and the frame synchronization data (T2, T1) received by the other station (2, 1); introducing a time delay or advance, according to the sign, in at least one of the frame synchronization data (T1, T2) of said pair of stations (1, 2) said time delay or advance having a duration in absolute value essentially equal to one half of the difference between said phase shift values (D12, D21). The present invention relates also to a system implementing this method.



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«METHOD AND SYSTEM TO SYNCHRONISE BASE STATIONS IN DIGITAL TELECOMMUNICATION NETWORKS»

Field of the invention

The present invention relates to a method to synchronise the base stations in digital telecommunication networks, in particular with time division duplex access or TDD (*Time Division Duplex*), such as for instance, the mobile radio telephone networks belonging to the DECT or UTMS standards. The present invention relates also to a system implementing this method.

It is well known that in mobile radio telephone networks with TDD access the transmission and reception of radio signals from and to the base stations, called RFP (*Radio Fixed Part*) in DECT environment and BS (*Base Station*) in UMTS environment, do not occur at the same time, but are alternated in a continuous sequence of periods having pre-set duration, each one called *frame* and properly coded and identified by the system. For instance, UMTS mobile radio telephone stations generally transmit the signals to mobile units in the first half of the frame or half-frame, and receive the signals transmitted by said mobile units in the second half-frame. In particular, each frame lasts 10 ms, subdivided into a predetermined number of time intervals or *timeslots*, they too having a predetermined duration.

Therefore, it is clear that to avoid dangerous interference between the base stations and the mobile units and/or to optimize the transfer of communications from a base station to the other one, according to a procedure called *handover*, it is necessary that frames are synchronized among them, so as to be able to separate the transmission and reception periods of the mobile units from those of the base stations and vice versa. Moreover, it is opportune that also the sequences of digital codes associated to each frame are aligned among base stations , in order to expedite the above mentioned *handover* procedure in the mobile units. This last synchronization type is called *multiframe*.

Background art

A known method to synchronize the frames consists in sending a reference impulse via cable, from a central control unit of the network, for instance the unit called RNC (*Radio Network Controller*) in UMTS environment, to the different base stations

belonging to the network itself. Measuring the time taken by each station in receiving said impulse from the moment of the transmission, we can determine and therefore compensate the propagation delay of the cable signal, to synchronize then the frames of radio signals. The results of this method can however be distorted by possible active devices present on the transmission lines, which can introduce variable delays in the propagation of the reference impulse and therefore it cannot assure an accurate synchronization.

Another known method is to synchronize the frames according to the time reference signal sent by the satellite transmitters GPS (*Global Positioning System*). Considering the high costs required for the installation of a GPS receiver in each station, this method results very expensive.

Object of the Invention

Object of the present invention is to eliminate the above mentioned drawbacks of said known synchronization methods and systems, through a new method and system whose main characteristics are specified in claims 1 and 11, respectively, while additional characteristics which are believed to be novel are set forth with particularity in the appended claims.

Summary of the Invention

Thanks to the use of radio signals transmitted and received directly by each base station to one or more adjacent stations, the method according to the present invention enables to reciprocally synchronize the frames of the signals of said stations without necessity of transmission lines or external devices. With this method, it is possible to avoid the installation of expensive satellite receivers, as in the method based on GPS signals. Moreover, the method according to the present invention does not exclude the recourse to the above-mentioned known methods, with which it is perfectly compatible and can be integrated.

Another advantage of the method according to the present invention is represented by the fact that it does not require particular dedicated means, but on the contrary can use the devices already present in the involved base stations and in other part of the mobile network, as well as their standard methods of radio transmission. In fact, the method according to the present invention does not necessarily require the use of supplementary messages or procedures in addition to those foreseen for the normal operation, but can employ those already existing.

According to a particular approach of the method according to the present

invention, it is possible not only to reciprocally synchronize the base stations, but also accurately determine their position, as well as those of the mobile units connected to them. Also for this function, the system does not require particular dedicated means, but can employ the devices already available in the network.

According to another profitable aspect of the method according to the present invention, the base stations are associated to particular hierarchical codes, through which it is possible to limit the propagation of possible measurement errors of the reciprocal phase shift as well as accelerating the execution times of the method itself.

Finally, the method according to the present invention can be profitably employed in telephone networks having structures that continuously change during time for the addition or removal of base stations, because the base stations can be synchronized with the adjacent stations in a completely automatic and dynamic manner. The different operating steps can actually be performed by the system without manual interventions and in any case without excluding the possible control of an operator, when desired.

Brief description of the Drawing

The invention, together with further objects and advantages thereof, may be understood with reference to the following description, taken in conjunction with the accompanying drawing and in which the unique figure shows a schematic view of the system implementing the method according to the present invention.

Detailed description of a preferred embodiment of the method according to the Invention

Making reference to said figure, we can see that the method according to the present embodiment of the invention includes, first of all, the transmission and reception by at least one pair of adjacent base stations 1, 2 of radio signals containing at least the relevant identification codes of station C1, C2 and the relevant frame synchronization data T1, T2 . At this point, each one of the stations 1 or 2 sends to a control unit 3, for instance the central control unit of a UMTS network, a signal containing the identification code C2 or C1 received by the adjacent station and the value of the phase shift D12 or D21 measured, for instance with an internal chronometer, between its own frame synchronization data T1 or T2 and the frame synchronization data T2 or T1, as received by the adjacent station 2 or 1.

The value of phase shifts D12, D21 consists of the sum of the contribution of the delay D due to the propagation time of the electromagnetic waves of the radio signal between stations 1, 2 and the value of the phase shift between frame synchronization

data T1 and T2, that is:

D12 = D + T1 - T2 , and

D21 = D + T2 - T1.

From the measurement of values D12 and D21, the control unit 3 can therefore obtain the real phase shift consisting of the difference T1 - T2 between the frame synchronization data T1 and T2, as well as the above mentioned delay D, as indicated here below:

T1 - T2 = (D12 - D21) / 2 , and

D = (D12 + D21) / 2.

Therefore, if we consider station 1 as main station, that is, we take as reference the frame synchronization data T1, the frame synchronization data T2 of station 2, considered as a secondary station, can be perfectly synchronized by the control unit 3 with the frame synchronization data T1 introducing a time delay or advance, according to the sign, having a duration essentially equal to (D12 - D21) / 2, that is equal to one half of the difference between the phase shifts D12 and D21 locally measured by stations 1 and 2. This synchronization procedure can be performed by the same control unit 3 or by station 2 following a specific command received by the control unit 3.

It is also possible to calculate the reciprocal distance S12 as the crow flies, between stations 1 and 2 by multiplying the delay contribution D, calculated as the mean between phase shift D12 and D21, by a propagation constant equal to the c propagation speed of electromagnetic waves in the air, that is:

S12 = c * D.

Once the frame synchronization data T1 and T2 of the stations 1 and 2 are synchronized between them, the station 2 can in its turn become a main station and therefore a time reference for possible other stations adjacent to it

In order to accelerate the execution times of the method according to the present invention, simultaneously decreasing the quantity of measurements of the reciprocal phase shifts between the frame synchronization data of the stations in the network, as well as the quantity of data to send to the control unit 3, the main stations, among which station 1 and station 2 already synchronized, can be marked by the state of specific hierarchical codes, in particular M1 and M2 respectively for station 1 and station 2. The secondary stations therefore could be synchronized only with the main stations marked in this way.

Once the frames of the stations 1 and 2 are synchronized between them, it is

possible to perform also a multiframe-synchronization among the same stations. To this purpose, station 1 can send to the control unit 3 the numeric code K associated to the frame in use in station 1, which is immediately sent to station 2 together with a particular command that orders to associate the same code K to the frame in use in station 2. As an alternative, the control unit 3 can simultaneously send to stations 1 and 2 a same digital code K with which frame sequences are numbered starting from the frame in use in both the stations. Considering that the transmission times of the code K between stations 1, 2 and the control unit 3 could include variable delays and/or delays higher than the duration of the frame in use, the control unit 3 can subsequently perform a simultaneous control of the frame in use in stations 1 and 2, possibly proceeding to a correction by attempts in case the frames in use would not coincide.

To synchronize all the stations belonging to a network among them, it is sufficient to reiterate the method described up to now with all the other secondary stations adjacent to station 1, as well as with all the secondary stations adjacent to station 2, and so on.

Since each secondary station synchronizes only with one main station adjacent to it, thus becoming a main station for additional secondary stations, it is evident that with this method, all the stations synchronized among them will shortly progressively spread out, up to cover the whole network, except of course for the isolated stations. For these stations, the known synchronization methods can however be employed, based for instance on GPS receivers or on the transmission of a reference impulse via cable, which are perfectly compatible with the method according to the present invention. The stations synchronized through these known methods could become in their turn main stations for other adjacent stations, which can be synchronised with the method according to the present invention.

The state of the hierarchical code of the main stations synchronized through a known method, in particular of the stations including a GPS receiver, can be differentiated by the state if the hierarchical code both of the secondary stations and of the main stations synchronized through the method according to the present invention. Through this measure, it can be checked and therefore restrained the propagation of possible measurement errors of the reciprocal phase shift among more stations arranged in cascade, in which said errors could cumulate among them.

For instance, in an embodiment of the method according to the present invention the secondary stations are identified by a hierarchical code equal to zero and the main

stations synchronized through an internal GPS receiver are marked by a hierarchical code equal to one. The main stations synchronized through the method according to the present invention and adjacent to the station with the GPS receiver are on the contrary marked by a hierarchical code equal to two, and so on, the hierarchical code of the main stations being increased by one unit at each synchronization procedure. In this case the hierarchical codes, for instance the codes M1 and M2 of the stations 1 and 2, are transmitted to the control unit 3 together with the identification codes C1 and C2 and to the values of phase shifts D12 and D21. If the hierarchical code M1 transmitted by the main station 1 is higher than a threshold value, the control unit 3 can start an automatic correction procedure or can warn with an error signal an operator who performs a manual correction of frame synchronization data T2 of station 2.

Said automatic correction procedure consists in sending via radio by the station 2 of a signal including its own identification code C2, its own hierarchical code M2, equal to the code M1 increased by one unit, as well as the value of the phase shift D21. If a station (not shown in the figure) adjacent to station 2 would receive said signal and have a hierarchical code higher than zero but lower than the hierarchical code M2 decreased by one unit, that is lower than the hierarchical code M1, this station could send a signal to the control unit 3, which in its turn would send a specific command to station 2, compelling the same to newly synchronize with the adjacent station having a hierarchical code lower than that of station 1. This new synchronization can be performed always with the method according to the present invention.

Finally, calculating the relative distances among all the stations of the network with the method indicated above for the calculation of the distance S12 between stations 1 and 2 and/or with possible GPS receivers, we can create a data base, for instance in an electronic processor placed in the control unit 3, which contains the geographic position of all the stations present in the network.

From this data base it is then possible to obtain a detailed topography of the network, as well as other information, such as for instance the geographic position of mobile units connected to the network itself. This last procedure can be implemented though a triangulation including the calculation of distances S14 and S24 between stations 1, 2 and a mobile unit 4 the position of which one wants to know, as well as the calculation of the distance between the same mobile unit 4 and an additional station (not shown in the figure) connected to the same. The calculation of said distances could be made for instance according to the known procedure of *timing advance*,

generally included in the UMTS standard.

An embodiment of the system implementing the method according to the present invention can be represented by a group of stations belonging to a mobile radio telephone network of the DECT or UMTS type. In absence of traffic channels, that is of connections established with one or more mobile units, a base station shall enable the transmission of at least one common signalling channel, called *dummy bearer* in DECT environment, to assure the transmission via radio of the system information necessary to the mobile units to have access to the network services. The identification codes C1, C2, the hierarchical codes M1, M2 and the frame synchronization data T1, T2 can belong to said system information. The channel of *dummy bearer* type employs a radio carrier in the band of the system and a *time slot* in the half-frame dedicated to the transmission. One base station enabled to the service has at least one radio channel always active in transmission, through which its own identification codes, its own hierarchical codes and its own frame synchronization data can be transmitted.

Therefore, in the system implementing the method of the present invention, base stations can perform a scanning to receive and decode the information contained in the *dummy bearers* channel transmitted via radio by the adjacent stations, so as to be able to obtain at any moment the identification codes, the hierarchical codes and the frame synchronization data of the adjacent stations.

While particular embodiments of the present invention have been shown and described, it should be understood that the present invention is not limited thereto since other embodiments may be made by those skilled in the art. It is thus contemplated that the present invention encompasses any and all such embodiments covered by the following claims.

CLAIMS

1. Method to reciprocally synchronize at least one pair of base stations (1, 2) belonging to a digital telecommunication network, in which the radio signals transmitted and received by said stations (1, 2) are subdivided into frames having pre-set duration and each frame is subdivided into a pre-set number of time slots including at least one field destined to the transmission of frame synchronization data (T1, T2), characterized in that it includes the following operating steps:

- transmitting by said pair of stations (1, 2) a radio signal containing at least its own frame synchronization data (T1, T2);
- receiving by said pair of stations (1, 2) the frame synchronization data (T2, T1) transmitted by the other station (2, 1);
- calculating by said pair of stations (1, 2) the phase shift values (D12, D21) between its own frame synchronization data (T1, T2) and the frame synchronization data (T2, T1) received by the other station (2, 1);
- introducing a time delay or advance, according to the sign, in at least one of the frame synchronization data (T1, T2) of said pair of stations (1, 2), said time delay or advance having a duration in absolute value essentially equal to one half of the difference between said phase shift values (D12, D21).

2. Method according to the previous claim, characterized in that it includes the following additional operational steps:

- associating at least one identification code (C1, C2) to said pair of stations (1, 2);
- transmitting by said pair of stations (1, 2) a radio signal containing at least its own identification codes (C1, C2);
- receiving by said pair of stations (1, 2) the identification codes (C2, C1) transmitted by the other station (2, 1);
- transmitting by said pair of stations (1, 2) to at least one control unit (3) a signal containing the phase shift values (D12, D21) among the frame synchronization data (T1, T2), their own identification codes (C1, C2) and the identification codes (C2, C1) transmitted by the other station (2, 1).

3. Method according to the previous claim, characterized in that it includes the following additional operating steps:

- associating at least one hierarchical code (M1, M2) to said pair of stations (1, 2);
- transmitting by at least one station (1, 2) a radio signal containing its own hierarchical code (M1, M2);

- receiving by at least one station (2, 1) the hierarchical code (M1, M2) transmitted by the other station (1, 2);
- changing the state of the hierarchical code (M2, M1) in at least one station (2, 1) according to the value of the hierarchical code (M1, M2) transmitted by the other station (1, 2).

4. Method according to the previous claim, characterized in that it includes the following additional operating steps:

- transmitting by said pair of stations (1, 2) to at least one control unit (3) the hierarchical codes (M2, M1) transmitted by the other station (1, 2);
- comparing the values of the hierarchical codes (M1, M2) of said pair of stations (1, 2);
- introducing of an additional time delay or advance, according to the sign, in at least one of the frame synchronization data (T1, T2) of said pair of stations (1, 2).

5. Method according to one of the previous claims, characterized in that it includes the following additional operating steps:

- transmitting by at least one of said stations (1, 2) a signal containing at least one digital code (K) associated to the frame in use;
- receiving by the other station (2) said digital code (K);
- associating said digital code (K) to the frame in use in said other station (2).

6. Method according to one of the claims 1 through 4, characterized in that it includes the following additional operating steps:

- transmitting by a control unit (3) to said pair of stations (1, 2) a signal containing a digital code (K);
- associating said digital code (K) to the frames in use in said pair of stations (1, 2).

7. Method according to the previous claim, characterized in that it includes the following additional operating steps:

- simultaneously controlling by the control unit (3) the frame in use in said pair of stations (1, 2);
- associating an additional same digital code to the frames in use in said pair of stations (1, 2).

8. Method according to one of the previous claims, characterized in that it includes the following additional operating steps:

- calculating the mean (D) of the reciprocal phase shift values (D12, D21) among the frame synchronization data (T1, T2) of said pair of stations (1, 2);

- calculating the reciprocal distance (S12) as the crow flies, between said pair of stations (1, 2) through the multiplication of said mean values (D) by a propagation constant of electromagnetic waves in the air.

9. Method according to the previous claim, characterized in that it includes the following additional operating steps:

- calculating the position of at least three adjacent stations connected to at least one mobile unit (4);
- calculating the distance as the crow flies, between said adjacent stations and said mobile unit (4);
- calculating the position of said mobile unit (4) according to the position of said adjacent stations and to the distance as the crow flies between said adjacent stations and said mobile unit (4).

10. Method according to one of the previous claims, characterized in that it includes the reiteration of said operating steps in all the stations reciprocally connected in the same digital telecommunication network.

11. System to reciprocally synchronise at least one pair of base stations (1, 2) belonging to a digital telecommunication network through the method according to one of the previous claims, in which the radio signals transmitted and received by said stations (1, 2) are subdivided into frames having pre-set duration and each frame is subdivided into a pre-set number of time slots, characterized in that said time slots include at least one field destined to the transmission of the frame synchronization data (T1, T2), at least one field destined to the transmission of identification codes (C1, C2) and of the hierarchical codes (M1, M2) of the stations themselves (1, 2).

12. System according to the previous claim, characterized in that the identification codes (C1, C2), hierarchical codes (M1, M2) and the frame synchronization data (T1, T2) are transmitted and received by the stations (1, 2) in a radio channel always active, which includes system information necessary to the mobile units to have access to network services.

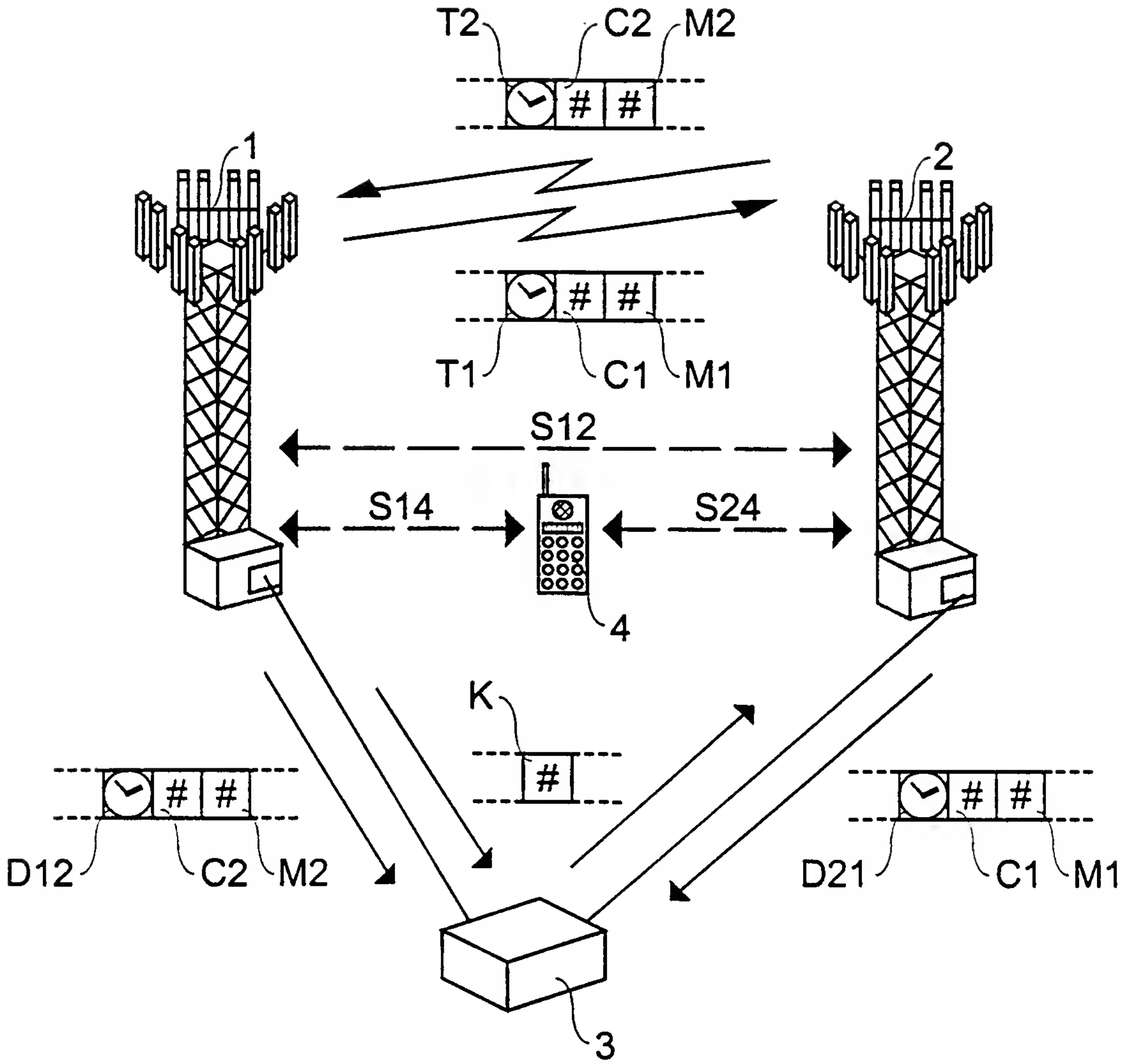

Fig.1